MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EPM2036 – CONTROL THEORY
(TE / RE / BE)

8 MARCH 2017
09:00a.m. – 11:00a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given .
3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Consider the block diagram shown in Figure Q1.1.
(i) Draw the equivalent signal flow graph. [6 marks]
(ii) Simplify the system and find the transfer function $Y(s)/R(s)$ by using Mason's Gain Formula. [7 marks]

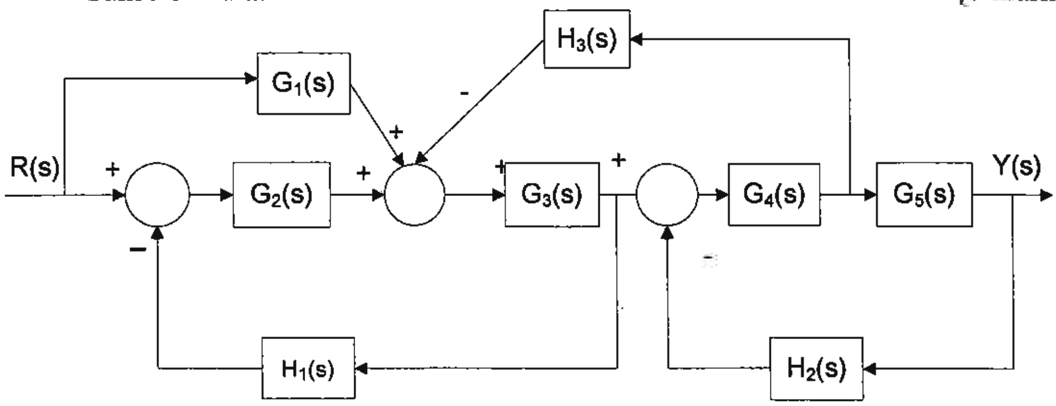

Figure Q1.1

(b) Find the transfer function $G(s) = \dfrac{\theta_2(s)}{T\ (s)}$ of the gear train system shown in Figure Q1.2 in terms of J_1, J_2, D_1, K_1, K_2, N_1 and N_2.
(J = moment of inertia, D = coefficient of viscous friction, K = spring constant and N = number of gear teeth) [12 marks]

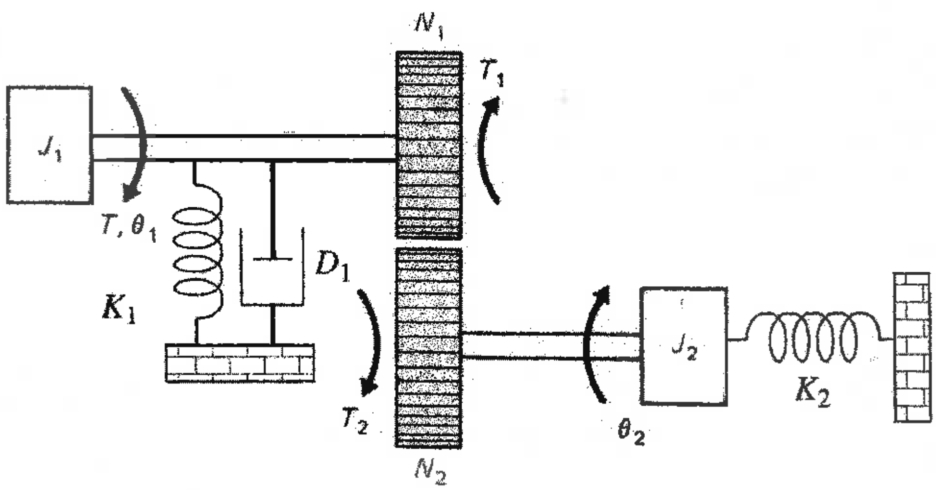

Figure Q1.2

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Question 2

(a) Routh-Hurwitz stability criterion is a method to determine the stability of a particular system. It is a method for determining the location of zeros of a polynomial with constant real coefficients with respect to the left-half and right-half of the s-plane, without actually solving for the zeros. Given the characteristic equation,

$$s^8 + 2s^7 + 8s^6 + 12s^5 + 20s^4 + 16s^3 + 16s^2 = 0$$

with the aid of Routh-Hurwitz criterion, find the **number of roots** located on the $j\omega$-axis.

[9 marks]

(b) Determine the stability of the following closed-loop transfer function:

$$T(s) = \frac{10}{s^5 + 2s^4 + 3s^3 + 6s^2 + 5s + 3}$$

[10 marks]

(c) Consider a non-unity negative feedback system with forward path transfer function $G(s) = \dfrac{1}{s^2(s+12)}$ and feedback path transfer function $H(s) = \dfrac{5(s+1)}{s+5}$. Calculate the steady-state error when a unit ramp input is applied to the system. [6 marks]

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Question 3

A negative unity feedback system has a forward path transfer function $G(s)$ given by

$$G(s)=\frac{K}{(s+1)(s+2)(s+3)(s+4)}.$$

(a) From the characteristic equation of the unity feedback system, find the following for the root locus:

(i) start and end points of all the branches, [2 marks]

(ii) asymptotes, [4 marks]

(iii) imaginary axis crossing points and the corresponding K value, [8 marks]

(iv) range of locus points on the real axis [2 marks]

(v) break-in/break-away points from the real axis [4 marks]

(b) Based on the answers to part (a), sketch the root locus of the system. [5 marks]

Question 4

(a) Consider a second-order negative feedback system with forward path transfer function $G(s)=\dfrac{w_n^2}{s(s+2\zeta w_n)}$ and feedback path transfer function $H(s)=1$. Show that the closed-loop bandwidth (defined by w) can be obtained by solving $w^4+2w_n^2(2\zeta^2-1)w^2-w_n^4=0$. [7 marks]

(b) A certain industrial plant synthesizes a chemical product from raw materials at high temperature in a reactor. It is required to design a controller for the system in order to control the temperature of the reactor, which is considered an important parameter affecting the quality of the chemical product. The transfer function between is input (desired temperature) and the output (actual temperature) is estimated to be

$$G_P(s)=\frac{1}{s(s+0.2)}$$

(i) The system is known to be lightly damped. Find the damping ratio of the system in closed-loop without any controller. [4 marks]

(ii) Design a Proportional-Derivative (PD) controller in order to improve the damping ratio by five times of the original value found part (a). It is also required that the steady-state error in response to a unit ramp input be equal to 0.01. [13 marks]

(iii) State, in general, one positive effect of improving the damping ratio of a lightly damped system. [1 mark]

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Appendix

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $u_s(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ $(n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
t^n $(n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$
$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$

End of Paper